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DISCREPANCIES BETWEEN STANDARDIZED MEASURES OF COGNITIVE LEVEL AND HALSTEAD-REITAN IMPAIRMENT INDICES AS INFERENCES OF BRAIN DAMAGE FOLLOWING HEAD INJURIES[1]

M. A. PERSINGER

Laurentian University

Summary.—z scores for measures of intelligence, memory, educational achievement, and neuropsychological impairment were obtained for 193 patients who had sustained impacts of mechanical energy to their skulls. Two sets of normative data, adjusted for age and sex and not adjusted for these variables, were employed to compute indices of neurocognitive proficiency (the inverse of impairment). 80% or 76 of the 96 patients whose Halstead-Reitan Indices were greater than 0.4 displayed scores for neurocognitive proficiency that were two or more standard deviations below the averages of their scores for intelligence, memory, and educational achievement. None of the patents whose Impairment Indices were 0.4 or less displayed this discrepancy. There were no statistically significant differences between these two groups of patients with respect to the presence of unconsciousness following the injury or the duration of posttraumatic memory disruptions. The results indicate that quantitative scores for neuropsychological impairments are still the most accurate criteria to discern brain dysfunction within the mild to moderate range.

Attempts to define brain damage *a priori* by employing a single variable such as the duration of unconsciousness or the duration of posttraumatic dysmnesia following the impact of mechanical energy to the skull ignores individual differences as the major source of numerical variance within a population. The manner in which mechanical energy is transmitted through brain tissue (Pang, 1989; Sweeney, 1992) and the forms of cellular changes that occur hours to weeks subsequent to the injury (Persinger, 1995b) are the major contributors to brain damage and the correlative compromise of neuropsychological proficiency (Parker, 1990; Persinger, 1995a, 1995b). This impairment can be masked by "clinical" presentations that are often superficially reinforced by the results of personality inventories whose items are derived from psychiatric concepts.

General psychometric theory and assumptions of normal distribution predict that the magnitudes of the standardized scores for a normal person's intelligence, memory capacity, and educational achievement should be similar. Consequently most normal people whose intelligence scores are 1.5 standard deviations above the mean should display scores of memory capacity

[1]Please send reprint requests to Dr. M. A. Persinger, Clinical Neuropsychology Laboratory, Department of Psychology, Laurentian University, Sudbury, Ontario, Canada P3E 2C6.

and educational achievement within that range. Most people whose intelligence scores are 1.5 standard deviations below the mean would be expected to display scores for memory capacity and educational achievement that are also within range of –1.5 standard deviations.

Because intelligence, memory, and educational achievement are ultimately products of brain function, the magnitude of a normal person's neurocognitive proficiency would be expected to be congruent with his level of intelligence, memory, and educational achievement. If, following a closed head injury, a previously successful banker displays standardized (z) scores between 0.5 and 1.5 for intelligence, memory, and educational achievement but a standardized score of –2.5 for neurocognitive proficiency, then a neuropsychological impairment would be indicated. The persistence of this level of deficit two to three years after the event, even after depression has been accommodated pharmacologically (Tiller & Persinger, 1998), would strongly suggest a permanent change in brain function that would be defined as damage.

If the banker had displayed this level of neurocognitive proficiency since childhood, his intelligence, memory, and educational achievement would be expected to have been within the borderline to below normal range (z lower than –2.00). The probability that he could have maintained the demands of the vocation before the incident would have been minimal. The purpose of the present study was to discern the quantitative relationships among various measures of neuropsychological impairment and to examine the distribution of standardized discrepancies between patients' cognitive capacities and their neurocognitive proficiencies in the context of traditional predictors of brain damage.

Method

Subjects

A total of 102 men and 91 women, who had been referred primarily by rehabilitation companies or by lawyers, served as subjects. They had sustained impacts of significant mechanical energies to their skulls. More than 80% of these cases involved motor vehicle incidents. This sample involved all of the adult (15 years of age or older) patients referred to us over an 8-yr. period. The general characteristics of the population are shown in Table 1.

Procedure

Each subject was assessed individually by an experienced psychometrist. Scores for the following procedures and tests were extracted for the present analysis: all of the components of the Halstead-Reitan Battery (Reitan & Wolfson, 1985), the Wechsler Adult Intelligence Scale (Revised), the Wechsler Memory Scale, Wide Range Achievement Test, Verbal Fluency, Design Fluency, Chicago Word Fluency, Auditory Closure, Dichotic Word Listen-

TABLE 1

MEANS, STANDARD DEVIATIONS, AND MINIMUM–MAXIMUM VALUES FOR MAJOR CHARACTERISTICS OF 193 PATIENTS IN THIS STUDY

Variable	*M*	*SD*	Mimumum	Maximum
Age, yr.	36.4	13.5	15	79
Halstead-Reitan Index	.5	.3	0	1.0
Verbal Intelligence IQ	88.2	10.7	47	122
Performance Intelligence IQ	93.1	13.1	58	135
Wechsler Memory Scale IQ	93.7	16.1	52	143
Average Educational Achievement	89.9	13.1	58	119
Period of Unconsciousness, hr.	11.5	28.9	0	99
Posttraumatic Dysmnesia, days	13.3	26.6	0	99
Time Since Injury, yr.	2.5	3.5	.1	23
Formal Education, yr.	11.7	2.8	1	19

Note.—Intelligence, memory, and educational achievement scores are expressed as standardized scores with a mean of 100 and standard deviation of 15.

ing, Conditioned Spatial Association Task, Sentence Memory, Spatial Span, Stroop Color-Word Test, Toe Gnosis, Toe Graphaesthesia, Foot Agility, Manipulative Dexterity (Pegboard), and the short version of the Minnesota Multiphasic Personality Inventory (Vincent, Castillo, Hauser, Zapata, Stuart, Cohn, & O'Shanick, 1984). More precise details and additional references for these tests have been published elsewhere (Persinger & Richards, 1995).

All of the standardized scores were transformed to *z* scores and were employed to obtained various aggregate scores. The person's general cognitive level was defined as the mean of four scores: the Verbal IQ, Performance IQ, Memory Quotient, and Educational Achievement. The last measure was the mean of the *z* scores for Spelling, Reading (decoding), and Arithmetic.

There were two standardized measures of the Halstead-Reitan Impairment Index (that ranges from 0 to 1) employed for this study. The first was derived from our norms. The means and standard deviations for these values are presented in Table 2. They were derived from a sample of 20 men and 20 women, ages 19 through 40 years, enrolled in university, and 15 men and 15 women, ages 30 through 59 years, who had been referred for issues other than acquired brain impairment. These individuals had reported no history of brain injury and were self-described as healthy during the past two years. The second standardized measure was derived from the age- and sex-adjusted norms of Elias, Robbins, Walter, and Schultz (1993). They obtained stratified norms as a function of 10-year increments for people between the ages of 15 years and 65 years (or older) for men and women separately.

In addition, a variant of the Halstead-Reitan Index was calculated. It was composed of the mean of the *z* scores for each of seven tests. Five of those tests are involved in the calculation of the Halstead-Reitan Index while

TABLE 2
MEANS AND STANDARD DEVIATIONS FOR HALSTEAD-REITAN INDEX AND TEST COMPRISING VARIANT INDEX FOR OUR NORMAL SAMPLE

Measure	*M*	*SD*
Halstead-Reitan Index	.3	.2
Finger Tap, avg. of both hands	52.3	6.8
Category, errors	31.3	17.4
Tactual Performance Test, min. (dominant plus nondominant)	7.3	1.9
Tactual Performance Test–Memory, number correct	8.3	0.8
Tactual Performance Test–Location, number correct	6.3	1.1
Trails A, sec.	27.3	6.0
Trails B, sec.	60.5	11.7

the remaining two, Trails A and Trails B, are a component of the battery but are not involved in the calculation of the Index. This variant was calculated to investigate the extent to which removing two tasks for central auditory processing (Seashore Test and Speech-Sounds Test) and adding two "prefrontal" tasks affected the strength of the various predictors. This variant was calculated by employing our norms and the norms of Elias, *et al.* (1993). The Laurentian University Impairment Index, the mean of 31 performance-based measures (Persinger, 1995a), was calculated for comparisons.

Analysis.—The first stage of the analysis was to obtain (1) the magnitudes of the correlations and (2) the values for slopes between the ordinal rankings of the severity of neuropsychological impairment as defined by the Halstead-Reitan Impairment Index and the mean values of the z scores for the various measures. The integers for the ordinal rankings and their descriptors, according to the unpublished norms of P. K. Remrock, were similar to the range of values reported by Russell, Neuringer, and Goldstein as published by Jarvis and Barth (1984). The integers and their descriptors were 0 (high normal), 1 (normal), 2 (mild impairment), 3 (moderate impairment), 4 (severe impairment), and 5 (very severe impairment). Regression equations were obtained between this ordinal ranking and (1) the z scores for the Halstead-Reitan Impairment Index, calculated from our norms and the norms of Elias, *et al.* (1993) and (2) the mean of the z scores, derived from the two normative sources, for the variant index. The inverse of the z scores for the Halstead-Reitan Impairment Index (obtained by multiplying -1 times the z score) and the means of the z scores for the variant index were called indicators of neuropsychological proficiency. Because they were derived from two sets of normative data, there were four indicators of neuropsychological proficiency.

In addition, regression equations were obtained between the same criterion variable (ordinal ranking of the severity of impairment) and (1) the mean z scores for the 31 measures that compose the Laurentian University

Impairment Index and (2) the *z* score from the Elias, *et al.* (1993) norms for the most impaired measure of the seven employed to calculate the variant index. To evaluate the strength of these relationships for the single most powerful test of the Halstead-Reitan Battery, regression equations were obtained for the ordinal ranking of the numbers of errors committed during the performance of the Category Test and the *z* scores from the two normative sources. These procedures were completed to examine the quantitative relationship between the successive ordinal rankings of the severity of neuropsychological impairment and the values of the mean *z* scores for the measures of neurocognitive proficiency.

The second stage of the analysis was to obtain scores of discrepancy between each patient's intellectual level (mean of the *z* scores for verbal intelligence and performance intelligence) and general cognitive level (mean of the *z* scores for verbal intelligence, performance intelligence, memory, and educational achievement), and the four scores for neuropsychological proficiency. The discrepancy scores were then compared by one-way analysis of variance as a function of the dichotomous criterion described by Reitan and Wolfson (1985), i.e., as within the range of brain damage (Halstead-Reitan Index of >0.4) or no brain damage (0.4 or lower). To evaluate the magnitude of any confounding contribution from age and time since the injury to the amount of variance in the discrepancy scores accommodated by the dichotomous criteria, the effect size was obtained for these differences after the shared variance between the discrepancy scores and age, the general cognitive level, or time since injury had been removed by covariance.

The third stage of the analysis was to obtain the distribution and overlap of the two populations defined as not brain-damaged or brain-damaged by the dichotomous score from the Impairment Index (Reitan & Wolfson, 1985). To inspect this distribution the values for the discrepancies between the *z* scores for the patients' general cognitive levels and the *z* scores for their neuropsychological proficiencies (–1 multiplied by the *z* score for the Halstead-Reitan Impairment Index from our norms) were obtained by subtraction. These discrepancies were then partitioned into intervals of 1 standard deviation. Chi-squared analysis was completed between the numbers of patients who met the criterion of brain damage or no brain damage and the successive intervals of 1 standard deviation between the general cognitive level and the neuropsychological proficiency.

To assess the extent to which reported suspension of consciousness or posttraumatic dysmnesia was associated with neuropsychological impairment and the discrepancies between measures of cognitive capacity and neuropsychological proficiency, Spearman *rho* correlations were completed among these measures. The possible differences in personality measures for patients who met or did not meet the criterion of brain injury (Reitan & Wolfson,

1985) were tested by one-way analyses of variance for each of the 10 clinical scales for the short version of the Minnesota Multiphasic Personality Inventory. All analysis involved SPSS software.

Results

The correlation coefficients, slopes, standard errors of the slopes and intercepts between the ordinal ranking of the severity of neuropsychological impairment (from 0, high normal, through 5, very severe impairment) and the means of the *z* scores for various combinations of neuropsychological tests (norm-referenced to either our norms or the age- and sex-adjusted norms) are shown in Table 3. The slopes for the regressions involving the ordinal rankings and the *z* scores for the Halstead-Reitan Index and the variant index for both our norms and the norms from Elias, *et al.* (1993) were approximately 1. This means that for every one standard deviation increase in the *z* score for neuropsychological impairment the ordinal ranking of the severity of impairment increased by one level. For the other measures, where a more positive score indicated proficiency, the slopes were negative. This means that for every decrease of one standard deviation the ordinal ranking of impairment increased by one level.

TABLE 3

Correlation Coefficients, Slopes, Standard Errors of Slopes, Intercepts, and Ranges For Predictors of Ordinal Ratings (0 Through 5) of Impairment Described by Russell, Neuringer, and Goldstein

Predictor	*r*	Characteristics				
		Slope	*SE*	Impairment Value Intercept		
				Y Intercept	2	4
Our Norms						
Halstead-Reitan Index *z*	.99	1.05	.01	1.38	.8	2.4
Halstead-Reitan Variant	−.86	− .82	.03	.50	−1.9	−4.2
Laurentian Index (31 variables)	−.84	−1.24	.05	.61	−1.0	−2.5
Elias, *et al.* Norms						
Halstead-Reitan Index *z*	.98	1.19	.01	.72	1.0	2.7
Halstead-Reitan Variant	−.82	−1.01	.05	.63	−1.1	−2.8
Maximum Impairment	−.75	− .80	.05	−.31	−3.0	−5.5
Category Test						
Our Norms	−.97	− .67	.01	.72	−1.8	−4.8
Elias Norms	−.90	− .71	.02	.91	−1.8	−4.6

The relationship between the qualitative range of impairment and the actual standard deviations are indicated by the values for the *z* score for the impairment at the intercept of the regression line. Ordinal values of 2 for the Halstead-Reitan Impairment Index, which would be considered within the range of a mild neuropsychological impairment, was associated with a composite *z* score of the equivalent of −1.00 or worse for all of the equa-

tions. Ordinal values of 4 for the impairment index, which would be considered indicative of neuropsychological impairment within the *severe* range was associated with standard deviations equivalent to –2.1 or below for all of the measures. The relationship between the ordinal ranking of the single most diagnostic test of prefrontal brain injury from the Halstead-Reitan Battery (the Category Test) and *z* scores from the two sets of norms are also shown.

Fig. 1 shows a scattergram of the relationship between the *z* scores of the variant index (mean of *z* scores for seven tests from the Halstead-Reitan Battery) of impairment derived from our norms and the age- and sex-adjusted norms of Elias, *et al.* (1993). The slope of 0.73 indicated that the increments of impairment depicted by our normative data, based upon university

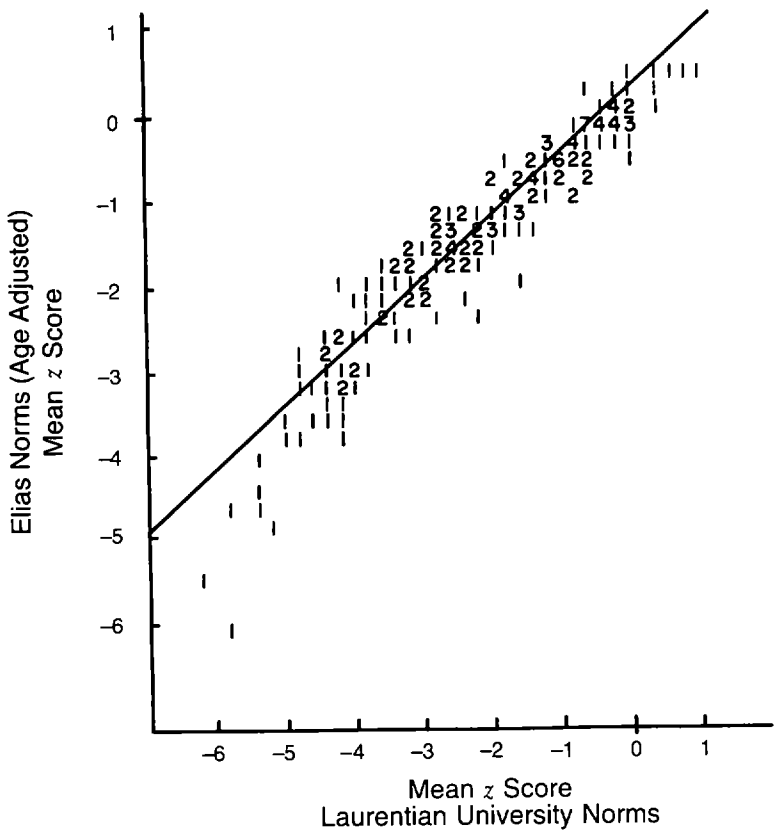

FIG. 1. Scattergram of relationship between the mean z scores of the seven measures that comprised the variant index derived from our norms and from Elias, *et al.* (1993) age- and sex-adjusted norms for 193 patients. $r = 0.95$, slope = 0.73.

students and nonuniversity normal adults, and those which were adjusted for successive increments of age and sex were nearly identical. This relationship indicated that the total contribution of age to disparities in slope, at least in this sample, were relatively minimal.

Table 4 shows the means and standard deviations of the various measures for the 97 patients whose Halstead-Reitan Impairment Index was 0.4 or less and for the 96 patients whose Index was 0.5 or greater. Because all of the mean differences were statistically significant at $p < .001$, except for educational achievement ($p < .01$), the effect sizes (as defined by η^2 values) are presented to indicate the magnitude of the differences. Except for the score for the single largest impairment of any of the seven scores that comprised the calculation of the variant index, all of the measures would be within the normal range for the patients who would not be considered brain-damaged. On the other hand, the patients whose impairment scores met the criterion of brain damage displayed standardized scores of more than two standard deviations below the mean. This indicates that the neuropsychological proficiency for at least half of this population would be abnormal and equivalent to intellectual scores within the mentally deficient range.

TABLE 4
MEANS AND STANDARD DEVIATIONS FOR VARIOUS MEASURES AS A FUNCTION OF PATIENTS' DICHOTOMOUS SCORE FOR HALSTEAD-REITAN INDEX OF 0.4 OR LESS (NO DAMAGE) OR 0.5 OR GREATER (DAMAGE)

Variable	No Brain Damage ($n=97$)		Brain-damage Range ($n=96$)		η^2 (%)
	M	*SD*	*M*	*SD*	
Verbal Intelligence	− .6	.6	−1.0	.7	10
Performance Intelligence	.0	.7	− .9	.7	27
Average Intelligence	− .3	.6	−1.0	.6	23
Memory Quotient	.0	.8	− .8	.9	12
Achievement	− .5	.8	− .8	.9	6
Cognitive Level	− .3	.7	− .9	.7	17
Our Norms					
Halstead-Reitan Index *z*	.3	.7	−2.1	.7	74
Halstead-Reitan Variant	−1.0	.9	−3.3	1.2	52
Laurentian University Index	− .6	.6	−2.1	.8	51
Elias, *et al.* Norms					
Halstead-Reitan Index	− .2	.6	−2.3	.7	77
Halstead-Reitan Variant	.6	.6	−2.1	.9	47
Largest Impairment	−2.3	1.1	−4.1	1.0	37
Neurocognitive-Cognitive Discrepancy					
Our Norms					
Halstead-Reitan Index–Average IQ	.1	1.1	−3.0	1.1	65
Halstead-Reitan Index–Cognitive Legel	.1	1.1	−2.9	1.1	64
Variant–Average IQ	− .7	.9	−2.3	1.1	40
Variant–Cognitive	− .8	.9	−2.4	1.1	41

Table 4 also contains the scores for discrepancy between the measures of neuropsychological proficiency and either the general intellectual level or the general cognitive level for the patients classified as brain-damaged or not damaged by the dichotomous Halstead-Reitan criterion. As predicted the discrepancy was minimal and within the range of random variation for patients who would be considered not brain-damaged. For our norms, the discrepancies for the patients who met the criteria of brain-damaged were at least two standard deviations. Table 5 shows the η values for the differences between the two groups of patients after the shared variances for age, time since the injury (truncated at 8 years to minimize skewness) and the general cognitive level had been removed separately.

TABLE 5

ETA VALUES FOR RESIDUALS OF DIFFERENCES BETWEEN PATIENTS WITH INDICES OF LESS THAN 0.4 OR 0.5 OR GREATER AFTER SHARED VARIANCE FOR EACH VARIABLE WITH AGE, GENERAL COGNITIVE LEVEL, OR TIME SINCE INJURY HAD BEEN REMOVED

Measure	Original	Age Removed	Time	Cognitive Level
Verbal Intelligence	.28	.42	.28	.08
Performance Intelligence	.51	.64	.51	.24
Average Intelligence	.46	.60	.46	.11
Memory (WMS) Quotient	.33	.51	.34	.01
Educational Achievement	.19	.28	.18	.16
General Cognitive Level	.42	.56	.41	
Our Norms				
Halstead-Reitan Impairment Index z	.86	.79	.86	.77
Variant Index	.73	.58	.73	.59
Laurentian University Index	.71	.59	.71	.54
Elias, *et al.* Norms				
Halstead-Reitan Impairment Index	.85	.80	.84	.75
Variant Index	.68	.58	.68	.53
Largest Impairment	.61	.54	.61	.45
Neuropsychological-General Cognitive Discrepancy				
Halstead-Reitan Index–Full Scale IQ	.80	.80	.81	.61
Halstead-Reitan Index–Cognitive Level	.80	.80	.80	.57
Variant–Full Scale	.63	.38	.63	.67
Variant–Cognitive Level	.64	.38	.64	.72

The numbers of patients with successive one standard deviation discrepancies between their general cognitive level and the neuropsychological proficiency are shown in Table 6. Patients who would not be considered brain-damaged displayed discrepancies that were distributed more or less normally around zero. Although the patients whose raw scores for the Impairment Index were 0.5 or greater displayed a near-Gaussian distribution of these discrepancies, the mean was shifted. For this population the scores for the discrepancies were distributed around values of between –2.00 and –3.00

TABLE 6
NUMBERS OF PATIENTS WITHIN INTERVALS OF DISCREPANCIES BETWEEN NEUROPSYCHOLOGICAL PROFICIENCY (INVERSE OF IMPAIRMENT) AND GENERAL COGNITIVE LEVEL AS A FUNCTION OF A HALSTEAD-REITAN INDEX OF 0.4 OR LESS OR 0.5 OR GREATER

z-score Discrepancy	No Damage	Damage
More than +2.00	3	0
+1.01 to +2.00	22	0
0.01 to +1.00	22	0
−0.99 to 0.00	30	7
−1.99 to −1.00	20	13
−2.99 to −2.00	0	30
−3.99 to −3.00	0	27
More than −4.00	0	19
Sum	97	96
Phi Coefficient	.85	

Note.—Negative discrepancies indicate the neurocognitive proficiency was less than the general cognitive level.

standard deviations. This indicates that the neurocognitive proficiencies for this population would be more than two standard deviations below their general cognitive levels.

Nonparametric (Spearman) correlations indicated no statistically significant associations ($p > .05$) among any of the measures presented in Table 4 and the time since injury, the reported presence of unconsciousness, or the duration of the disruption of memory. This result was clear for the entire population of 193 patients and when the two populations were analyzed separately. The means and standard deviations for the square roots of the duration of coma or memory disruption for the patients who did not meet the criterion of brain injury were 1.7 hr., 2.8 hr., and 2.5 days and 1.8 days, respectively, for the patients with scores of 0.4 or less and 1.5 hr., 3.2 hr., and 1.9 days, 2.9 days, respectively, for the patients with scores of 0.5 or greater. Kruskal-Wallis analyses indicated no statistically significant group differences ($\chi^2 < 3.45$, ns).

Except for the score for the memory quotient, none of the scores in Table 4 were significantly ($p < .001$) correlated with the clinical scales from the personality inventory. The correlations (Spearman *rhos*) between memory and these scales were for Depression −.25, Psychasthenia −.31, and Social Introversion −.26. To discern whether these correlations were related to the same source of variance, factor scores were obtained (after varimax rotation) for the 10 scales. Only these three scales were loaded significantly (r values $> .40$) on the second factor (of three factors) whose eigenvalue was 1.18 and which explained 12% of the variance. Only the scores for this factor were significantly and negatively ($rho = -.25$) correlated with the memory scores.

There were no statistically significant differences between the patients

whose Halstead-Reitan Impairment Indices were 0.4 or less or 0.5 or greater for the following scales from the short version of the Minnesota Multiphasic Inventory. The scales, grand means, and standard deviations were for Hypochondriasis 73 and 16, Depression 77 and 15, Hysteria 72 and 12, Psychopathic Deviancy 68 and 13, Gender (MF) 54 and 13, Paranoia 64 and 13, Psychasthenia 72 and 16, Schizoid 67 and 17, and Social Introversion 58 and 11. However, the patients who met the criterion of brain injury displayed significantly ($F_{1,191} = 8.81$, $p < .01$) lower scores (65 and 14) for Hypomania than did the patients who did not meet this criterion (71 and 11). Interesting, the third factor that emerged from the factor analysis, loaded significantly and positively by Psychopathic Deviancy (.49), Paranoia (.60), Schizoid (.50), and Hypomania (.81) scores, demonstrated statistically significant group differences ($F_{1,191} = 6.10$, $p = .01$). The patients whose impairment scores were 0.4 or less displayed higher standardized scores for this factor ($M = 0.16$, $SD = .82$) relative to the patients whose scores were 0.5 or greater ($M = -.18$, $SD = 1.1$).

To investigate if personality variables were confounding the large differences in neuropsychological indicators between the patients whose scores for impairment were 0.4 or less or 0.5 or greater, the shared variance between each of the measures for neuropsychological impairment and discrepancy (Table 4) and each of three aggregates of personality scales were removed before the analysis. The three aggregates of personality scales were the mean of all 10 clinical scales, the mean of Hypochondria, Depression, Hysteria, and Psychasthenia, and the mean of Psychopathic Deviancy, Paranoia, Schizoid, and Hypomania. After removal of these shared variances, the η values for the group differences for any of the neuropsychological variables did not change by more than the absolute value of .02.

Discussion

The employment of actuarial criteria and norm-referenced scores for the accurate and objective evaluation of patients has been emphasized frequently (Dawes, Faust, & Meehl, 1989). Many clinical neuropsychologists, however, continue to depend primarily upon their clinical impressions about their patients rather than upon norm-referenced scores to diagnose the presence or absence of brain injury. Many patients who have sustained brain injuries, as reflected by mild to moderate neuropsychological impairments, would not be easily detected by the method of clinical impressions.

In some instances the collection of the test data appears to be a rationalization for the legitimacy of the neuropsychologist's impression rather than the ultimate source of the diagnosis. Frequent arguments in many reports of neuropsychological assessments are that normative data are "too ambiguous," "there are too many problems with published norms," or "go-

ing by the numbers is misleading." As a result the conclusions of these clinical neuropsychologists become vulnerable to influence by the demands of insurance companies or lawyers, to the intrinsic biases of impressions of other professionals (read during the review of the patient's history), and to the inflated relevance of "special signs" displayed by the patient as indicators of "psychological causes" for test deficits.

The results of the present study indicate that traditional criteria for neuropsychological impairment are very consistent and reflect psychometric assumptions that define abnormality Reference data from two separate samples, one of which had been adjusted for age and sex (Elias, *et al.*, 1993), yielded similar values. The results also indicated that patients who would have met the criterion of brain damage, as defined by Reitan and Wolfson (1985), displayed standardized deficits or magnitudes of discrepancy between their general cognitive level and neurocognitive proficiency that overlapped only marginally with the patients who did not meet this criterion.

In the present population of 193 patients, the discrepancy between the person's general cognitive level and neurocognitive proficiency was a powerful discriminator of the criteria for brain damage. Approximately 80% of the patients whose scores were within the brain-damaged range also displayed discrepancies of two standard deviations or more between the scores for neuropsychological proficiency and general cognitive level. None of the patients whose Impairment Index was 0.4 or less displayed this vector in discrepancy. Sex, time since the injury, or chronological age did not substantially affect the magnitude of the most powerful discrepancy between the two populations of patients.

There were no statistically significant correlations, even when nonparametric analyses were employed to minimize distortions from outliers, between the duration of unconsciousness or of the estimated posttraumatic memory disruptions following the mechanical impact and either the severity of the neuropsychological impairment or the discrepancy between the neuropsychological proficiency and the general cognitive level. Except for a weakly significant difference for the Hypomania scale of the Minnesota Multiphasic Personality Inventory, the scores from scales that have been inferred to reflect "neurosis" or "psychosis" did not differ between the two populations. These results again suggest that the employment of personality scores as indicators of evidence for the presence or absence of neuropsychological impairments and the attribution of these deficits to "psychological causes" may not be as valid as presumed.

The explosive dispersion of quanta of mechanical energy through brain tissue can result in permanent changes in brain function (Persinger, 1995b). Even the most sophisticated tools of brain imaging, such as Positron Emission Tomography (PET) or functional Magnetic Resonance Imaging (fMRI),

reflect the grosser metabolic activity of large aggregates of neurons. The microspatial effects from acceleration forces (Sweeny, 1992) upon permanent cellular changes, which could be manifested in forms that range from diffuse axonal injury to altered expressions of receptor subtypes, would not be discerned. Were these changes permanent, they would constitute brain damage. Until these methods achieve much higher resolution, the applications of the principles of behavioral neuroscience (Persinger, 1995b) to the numerical characteristics of norm-referenced scores obtained from thorough clinical neuropsychological assessments are still the most valid quantitative indicators of anomalies in brain functions.

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